

Assessing Heterogeneous Influences on Partial Deposition of Virus in Lateritic and Silty Formation: Applying Predictive Model, Patani, Bayelsa State of Nigeria

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Abstract— This paper monitored the rate of partial deposition of virus on heterogeneous formation, the study were able to monitor the behaviour of virus in heterogeneous deposition influencing partial concentration of virus in Lateritic and silty formation. The study was able to observe the rate of partial deposition base on its rate of fluctuation through variation observed from deposited void ratio and permeability, such formation developed fluctuation on these parameters thus generated partial deposition of virus in the study area. Linear deposition were also experienced in graphical representation, the result obtained ranged from $[1.97E-12-2.35E-11]$, $[3-30M]$, $[1.97E-12-2.36E-11]$ $[10-100]$ Predictive $1.97E-12$, Experimental $1.87E-12$ $[3-36m]$, predictive, $[1.97E-12]$, Experimental $[2.26E-11]$ $[10-120 Days]$ predictive $2.36E-12$, Experimental $2.24E-11$, $[10-120Days]$ $[1.31E-12-2.36E11]$, Predictive $1.31E-12$, Experimental, $2.36E-11$ $[2-30m]$, predictive, $[2.36E-11-2.2E-11]$; $[2-30m]$, for Time $1.31E-12-2.36E-11$ $[4-60days]$ while predictive and Experimental, $[2.36E-11]$ $[1.37E-12-2.22E-11]$ $[2-30m]$ The prediction rate of partial deposition of virus was possible through mathematical modeling techniques, the system were developed base on the parameters from predominant formation characteristics in study location, these parameters generated the derived model through the developed governing equation, simulation generated theoretical values that were compared with experimental results, both parameters developed best fits validating the model, experts will definitely applied this approach in monitoring and evaluation of virus deposits in the study area.

Keywords— modeling, heterogeneous, partial virus lateritic and silty formation.

I. INTRODUCTION

Indicator organisms are frequently used in place of disease causing pathogens because their presence is indicative of pathogen presence and indicator organisms are easier to detect. Another reason for using simple indicator tests is that pollution is often irregular. There is a need to investigate the suitability of these indicators for their use in tropical environments for the detection of recent fecal contamination in drinking water supplies. Extensive research has already been carried out in this area. These indicators have different characteristics and their significance to the microbial quality of drinking water can vary depending on the monitoring region. The ability to enumerate indicator organisms is particularly important when assessing the performance of a water treatment device such as a water filter. It allows the researcher to calculate microbial removal efficiency by finding out how much of the indicator organisms are removed by the filter (Eluozo and. Afiibor 2013) since the quality of the water supply is often variable and cannot be adequately controlled for millions of people in developing countries, one viable approach could be the implementation of simple, low cost point of use (POU) treatment systems to ensure the provision of safe water for consumption. Point of use treatment systems refer to the treatment of water at the household level as opposed to centralized, larger capacity municipal or private systems that carry out treatment of water for a larger population. Examples of these organisms include Pseudomonas, Klebsiella, and Legionella (WHO,

1996) for pathogens of fecal origin, drinking water is the main route of transmission. Unhygienic practices during the handling of food, utensils and clothing also play an important role. Humans are typically the main carriers of large populations of these bacteria, protozoa, and viruses (WHO, 1996). Pathogens originating from human sources, often from human feces, are called enteric the intestine of many domestic and wild animals, their meat, milk and dairy products, are sources of the bacteria *Yersinia enterocolitica* and *Campylobacter* (WHO, 1996). T Bacteria are single celled prokaryotes (without nucleus) with sizes ranging from 0.3 to 100 micrometers (μm) in length (Metcalf and Eddy, 1991 (Eluozo and. Afiibor, 2013) Therefore, these organisms can survive for long periods in water habitats (WHO, 1996). *Shigella*, also part of Enterobacteriaceae, causes dysentery in humans and is usually transmitted through direct contact. Other bacteria species of significance but not part of this family include the following: *Vibrio cholerae*, specifically the serogroups, causes cholera, an acute intestinal disease with massive diarrhea, vomiting, dehydration, possibly leading to death. Some other pathogenic bacteria include *Campylobacter* and opportunistic pathogens such as *Legionella pneumophila* and *Aeromonas E.coli* are characterized by their ability to produce potent Enterotoxins. Enterotoxins are similar to hormones which act on the small intestine, causing massive secretion of fluids which lead to the symptoms of diarrhea (Madigan et al., 2000, Chian, 2001). The disease was produced in two primates when they were given a dose of only 10 oocysts (Miller et al., 1990). While these indicator bacteria or viruses are not necessarily pathogenic themselves, some of them have the same fecal source as the pathogenic bacteria and can therefore indicate fecal contamination of water (WHO, 1993a). The main concern is to prevent the contamination of soil and water by the leachates that originates in the decomposition of the solid waste inside landfills (Kjeldsen et al., 2002). The volume and chemical composition of leachates depends on the water that infiltrates in the landfill, and on the chemical reactions between the solid and liquid phases, including dissolution, precipitation, ion exchange and biochemical processes. Leachates migration from inside the landfill cell to the vadose zone is prevented by low permeability liners (Petrov and Rowe, 1997; Guyonnet et al., 2005; Touze Foltz et al., 2006 Francisca, 2010), which usually have multiple layers of compacted clay, granular filters and geosynthetics. Compacted clays or mixtures of local soils with clay are frequently used to achieve very low hydraulic conductivity barriers and prevent subsurface contamination. The hydraulic conductivity can be further reduced by the

addition of Bentonite to local soils to attain the values specified by international regulations (10^{-7} cm/s) (Kayabali, 1997; Goldman et al., 1998). The ability of compacted soil liners to restrict the movement of water and contaminants depends on particle size, void ratio, specific surface, degree of saturation, and fluid properties (Vukovid and Soro, 1992; Foged and Baumann, 1999). Soil fabric, compaction energy and thixotropy are also relevant properties (Daniel and Benson, 1990; Benson and Trast, 1995). Different particle associations created during compaction generate either flocculated or dispersed soil fabrics, and are of fundamental importance in the soil hydraulic conductivity (Mitchell et al., 1965). In the past two decades, several studies were conducted to evaluate how soil and liquid properties control the hydraulic conductivity of soil liners (Mitchell et al., 1965; Mitchell and Jaber, 1990; Gleason et al., 1997; Schmitz, 2006). In general, the hydraulic conductivity of soils decreases with increasing fine particle content (Sivapullaiah et al., 2000). At high mechanical stress levels and in the case of highly compacted soils, electrical forces have negligible effect on soil behavior and soil fabric is slightly affected by the chemical properties of the permeating liquid (Mitchell and Soga, 2005).

II. DEVELOPED GOVERNING EQUATION

$$K \frac{hA}{L} \frac{\partial c}{\partial t} = \Delta V \frac{\partial^2 c}{\partial z^2} + h_{(x)} \frac{\partial c}{\partial z} + \Delta \phi \frac{\partial^2 c}{\partial z^2} \dots\dots\dots (1)$$

Nomenclature

h	=	Fluid flow at vertical level
K	=	Permeability
A	=	Cross sectional area
L	=	Length
T	=	Time
Q	=	Porosity
c	=	Concentration
V	=	Velocity
z	=	Depth
$h_{(x)}$	=	Fluid at short distance

$$K \frac{hA}{L} \frac{\partial c}{\partial t} = [\Delta V + \Delta \phi] \frac{\partial^2 c}{\partial z^2} + h \frac{\partial c}{\partial z} \dots\dots\dots (2)$$

$$K \frac{hA}{L} \frac{\partial c}{\partial t} = [\Delta V + \Delta \phi] \frac{\partial^2 c}{\partial z^2} \dots\dots\dots (3)$$

$$K \frac{hA}{L} \frac{\partial c_1}{\partial t} = h \frac{\partial c}{\partial z} \dots\dots\dots (4)$$

$$[\Delta V + \Delta \phi] \frac{\partial^2 c_3}{\partial z^2} = -h \frac{\partial c_3}{\partial z} \dots\dots\dots (5)$$

The solution is of the form

$$c = (t, z) = c_1(t, z) + c_2(t, z) + c_3(t, z)$$

$$\text{Let } c = T, Z \quad \dots\dots\dots (6)$$

$$\frac{\partial c_1}{\partial t} = T^1 Z \quad \dots\dots\dots (7)$$

$$\frac{\partial c}{\partial z} = TZ^1 \quad \dots\dots\dots (8)$$

$$\frac{\partial^2 c}{\partial z^2} = TZ^{11} \quad \dots\dots\dots (9)$$

Consider (3)

$$K \frac{hA}{L} T^1 Z = [\Delta V + \Delta \phi] TZ^{11} = \beta^2 \quad \dots\dots\dots (10)$$

$$K \frac{hA}{L} = \beta^2 \quad \dots\dots\dots (11)$$

$$\int \frac{dT}{T} = \int \frac{\beta^2}{K \frac{hA}{L}} dt \quad \dots\dots\dots (12)$$

$$\ln T = \frac{\beta^2}{K \frac{hA}{L}} + c \quad \dots\dots\dots (13)$$

$$T = A \ell^{\frac{\beta^2}{K \frac{hA}{L}} t} \quad \dots\dots\dots (14)$$

Considering this expression again $[\Delta V + \Delta \phi] = \beta^2$

$$[\Delta V + \Delta \phi] Z^{11} = \beta^2 \quad \dots\dots\dots (15)$$

$$c = B \ell^{\frac{\beta^2}{\Delta V + \Delta \phi} Z} + D \ell^{\frac{\beta^2}{\Delta V + \Delta \phi} Z} \quad \dots\dots\dots (16)$$

Combine (14) and (16) gives

$$c_1(t, z) = \left(B \ell^{\frac{\beta^2}{\Delta V + \Delta \phi} Z} + D \ell^{\frac{\beta^2}{\Delta V + \Delta \phi} Z} \right) A \ell^{\frac{\beta^2}{K \frac{hA}{L}} t} \quad \dots\dots (17)$$

Consider equation (4)

$$K \frac{hA}{L} \frac{\partial c_2}{\partial t} = h \frac{\partial c_2}{\partial z}$$

$$K \frac{hA}{L} T^1 Z = h Z^1 T$$

$$K \frac{hA}{L} \frac{T^1}{T} = h \frac{Z^1}{Z} = \gamma \quad \dots\dots\dots (18)$$

$$h \frac{Z^1}{Z} = \gamma \quad \dots\dots\dots (19)$$

$$\int \frac{dT}{T} = \frac{\gamma}{K \frac{hA}{L}} \int dt \quad \dots\dots\dots (20)$$

$$\ln T = \frac{\gamma}{K \frac{hA}{L}} + \phi \quad \dots\dots\dots (21)$$

$$T = C \ell^{\frac{\gamma}{K \frac{hA}{L}} t} \quad \dots\dots\dots (22)$$

Considering $h \frac{Z^1}{Z} = \gamma$

$$\int \frac{dz}{z} = \int \gamma dz \quad \dots\dots\dots (23)$$

$$\ln z = \gamma z + b \quad \dots\dots\dots (24)$$

$$z = \Delta \ell^{\gamma h} \quad \dots\dots\dots (25)$$

Combine (22) and (25), gives;

$$c_2 = (t, z) = a b \ell^{\left(\frac{1}{K \frac{hA}{L}} + h \right) t} \quad \dots\dots\dots (26)$$

Consider equation (5)

$$[\Delta V + \Delta \phi] Z^{11} T = -h Z^1 T$$

$$[\Delta V + \Delta \phi] \frac{Z^{11}}{Z} = -h \frac{dz}{dz} = \theta^2 \quad \dots\dots\dots (27)$$

$$[\Delta V + \Delta \phi] \frac{d^2 z}{dz^2} = \theta^2 \quad \dots\dots\dots (28)$$

$$Z = E \cos \frac{\theta}{\sqrt{\Delta V + \Delta \phi}} z + F \sin \frac{\theta}{\sqrt{\Delta V + \Delta \phi}} z \quad \dots\dots\dots (29)$$

$$\text{Also } h \frac{dz}{dz} = + \theta^2$$

$$\int \frac{dz}{dz} = h \theta^2 \int dz \quad \dots\dots\dots (30)$$

$$\ln z = h \theta^2 z + d \quad \dots\dots\dots (31)$$

$$z = D \ell^{h \theta^2} \quad \dots\dots\dots (32)$$

Combining (29) and (30) yield

$$c_3(t, z) = \left(E \cos \frac{\theta}{\sqrt{\Delta V + \Delta \phi}} z + F \sin \frac{\theta}{\sqrt{\Delta V + \Delta \phi}} z \right) G e^{h\theta^2} \quad (33)$$

Therefore, combined equations (17), (26) and (33) give

$$c(t, z) = c_1(t, z) + c_2(t, z) + c_3(t, z)$$

$$c_1(t, z) = \left(B e^{\frac{\beta}{\Delta V + \Delta \phi} z} + D e^{-\frac{\beta}{\Delta V + \Delta \phi} z} \right) A e^{\frac{\theta^2}{K \frac{hA}{L}} t} + a b e^{\left(\frac{1}{K \frac{hA}{L}} + h \right) \gamma} + \left(E \cos \frac{\theta}{\sqrt{\Delta V + \Delta \phi}} z + F \sin \frac{\theta}{\sqrt{\Delta V + \Delta \phi}} z \right) G e^{h\theta^2} \quad (34)$$

III. MATERIALS AND METHOD

Standard laboratory experiment where performed to monitor the rate of virus concentration using column experiment at different formation, the soil deposition of the strata were collected in sequences base on the structural deposition at different locations, this samples collected at different location generate variation at different depth producing different migration of virus concentration through pressure flow at lower end of the column, the experimental result are applied to be compared with the theoretical values for model validation.

IV. RESULTS AND DISCUSSION

Results and discussion are presented in tables including graphical representation of pathogen concentration bellow:

Table.1: Theoretical values of virus concentration at Different Depths

Depth [M]	Concentration
3	1.97E-12
6	3.74E-12
9	5.92E-12
12	7.89E-12
15	9.87E-12
18	1.18E-11
21	1.37E-11
24	1.57E-11
27	1.77E-11
30	1.96E-11
33	2.16E-11
36	2.36E-11

Table.2: Theoretical values of virus concentration at Different Time

Time per Day	Concentration
10	1.97E-12
20	3.74E-12
30	5.92E-12
40	7.89E-12
50	9.87E-12
60	1.18E-11
70	1.37E-11
80	1.57E-11
90	1.77E-11
100	1.96E-11
110	2.16E-11
120	2.36E-11

Table.3: Comparison of Theoretical and Measured Values of virus Concentration Different Depth

Depth [M]	Theoretical Values Conc. mg/l	Experimental values mg/l
3	1.97E-12	1.87E-12
6	3.74E-12	3.55E-12
9	5.92E-12	6.11E-12
12	7.89E-12	7.56E-12
15	9.87E-12	9.66E-12
18	1.18E-11	1.09E-11
21	1.37E-11	1.24E-11
24	1.57E-11	1.45E-11
27	1.77E-11	1.66E-11
30	1.96E-11	1.90E-11
33	2.16E-11	2.09E-11
36	2.36E-11	2.26E-11

Table.4: Comparison of Theoretical and Measured Values of virus Concentration Different Depth

Time per Day	Theoretical Values Conc. mg/l	Experimental values mg/l
10	1.97E-12	1.67E-12
20	3.74E-12	3.66E-12
30	5.92E-12	5.88E-12
40	7.89E-12	7.77E-12
50	9.87E-12	9.77E-12
60	1.18E-11	1.11E-11
70	1.37E-11	1.31E-11

80	1.57E-11	1.51E-11
90	1.77E-11	1.72E-11
100	1.96E-11	1.91E-11
110	2.16E-11	2.09E-11
120	2.36E-11	2.24E-11

Table.5: Theoretical values of virus concentration at Different Time

Time Per Day	Concentration
4	1.31E-12
8	2.62E-12
12	3.93E-12
16	5.25E-12
20	6.55E-12
24	7.87E-12
28	9.19E-12
32	1.05E-11
36	1.18E-11
40	1.31E-11
44	1.44E-11
48	1.57E-11
52	1.70E-11
56	1.96E-11
60	2.36E-11

Table.6: Theoretical values of virus concentration at Different Depths

Depth [M]	Concentration
2	1.31E-12
4	2.62E-12
6	3.93E-12
8	5.25E-12
10	6.55E-12
12	7.87E-12
14	9.19E-12
16	1.05E-11
18	1.18E-11
20	1.31E-11
22	1.44E-11
24	1.57E-11
26	1.70E-11
28	1.96E-11
30	2.36E-11

Table.7: Comparison of Theoretical and Measured Values of virus Concentration Different Depth

Depth [M]	Theoretical Values	Experimental Values [mg/l]
2	1.31E-12	1.37E-12
4	2.62E-12	2.44E-12
6	3.93E-12	3.88E-12
8	5.25E-12	5.11E-12
10	6.55E-12	6.33E-12
12	7.87E-12	7.55E-12
14	9.19E-12	9.22E-12
16	1.05E-11	1.09E-11
18	1.18E-11	1.18E-11
20	1.31E-11	1.24E-11
22	1.44E-11	1.34E-11
24	1.57E-11	1.48E-11
26	1.70E-11	1.64E-11
28	1.96E-11	1.87E-11
30	2.36E-11	2.22E-11

Table.8: Comparison of Theoretical and Measured Values of virus Concentration Different Depth

Time Per Day	Theoretical values	Experimental Values
4	1.31E-12	1.34E-12
8	2.62E-12	2.55E-12
12	3.93E-12	3.88E-12
16	5.25E-12	5.31E-12
20	6.55E-12	6.41E-12
24	7.87E-12	7.74E-12
28	9.19E-12	9.22E-12
32	1.05E-11	1.10E-11
36	1.18E-11	1.16E-11
40	1.31E-11	1.29E-11
44	1.44E-11	1.38E-11
48	1.57E-11	1.45E-11
52	1.70E-11	1.64E-11
56	1.96E-11	1.88E-11
60	2.36E-11	2.21E-11

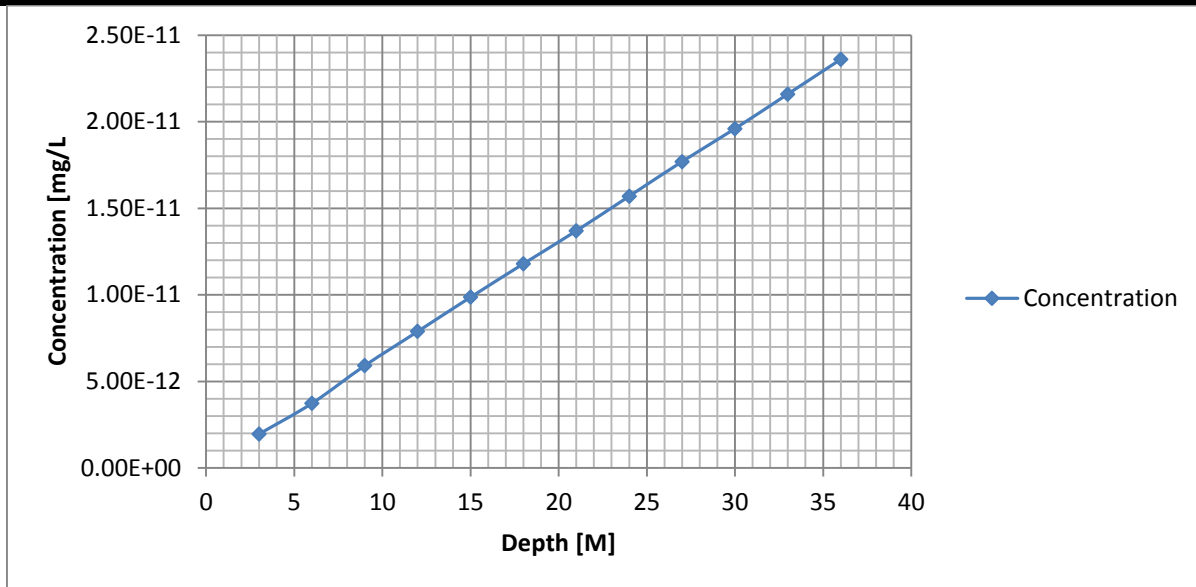


Fig.1: Theoretical values of virus concentration at Different Depths

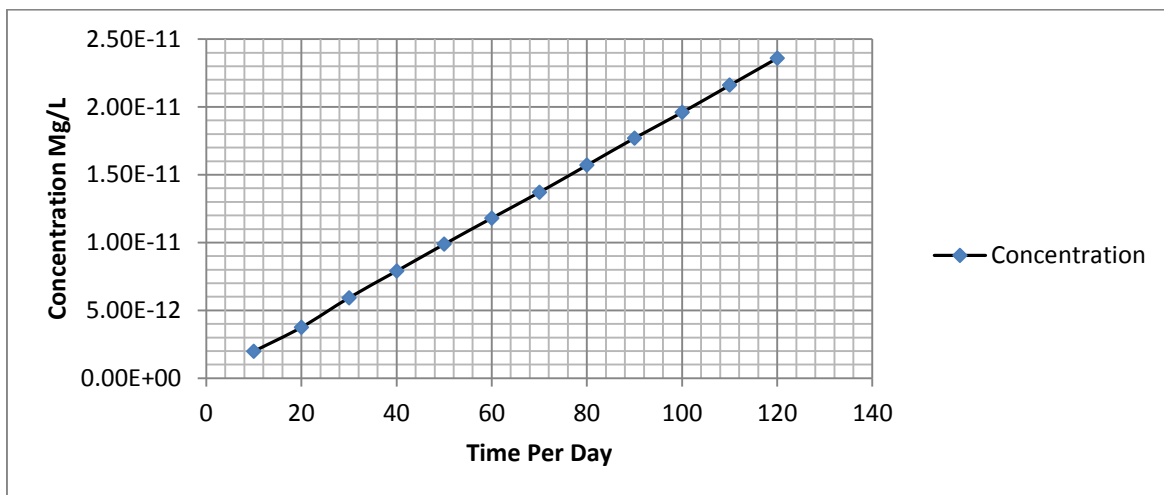


Fig.2: Theoretical values of virus concentration at Different Time

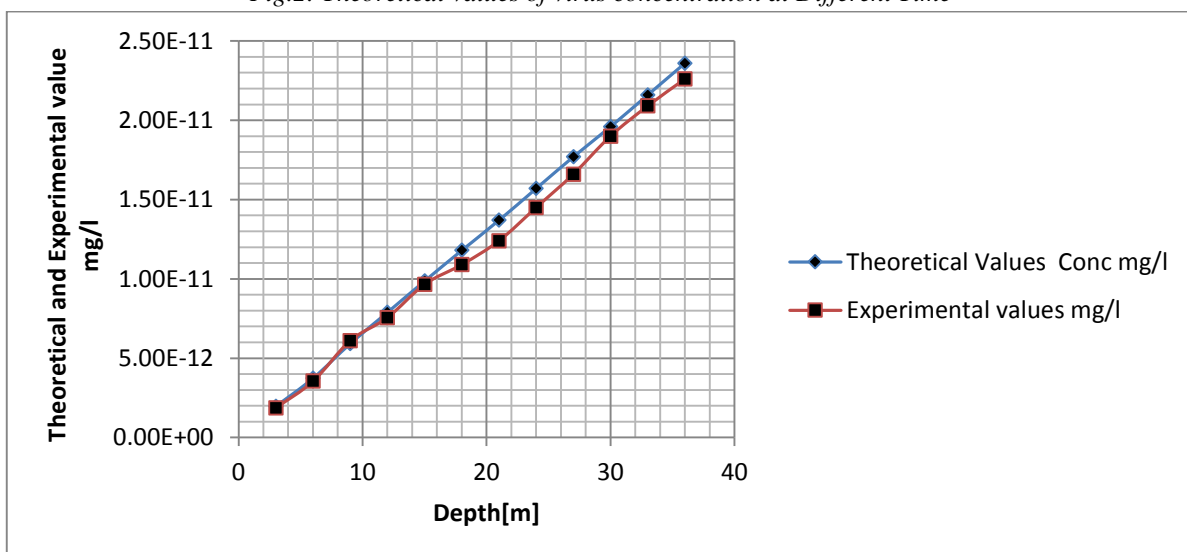


Fig.3: Comparison of Theoretical and Measured Values of virus Concentration Different Depth

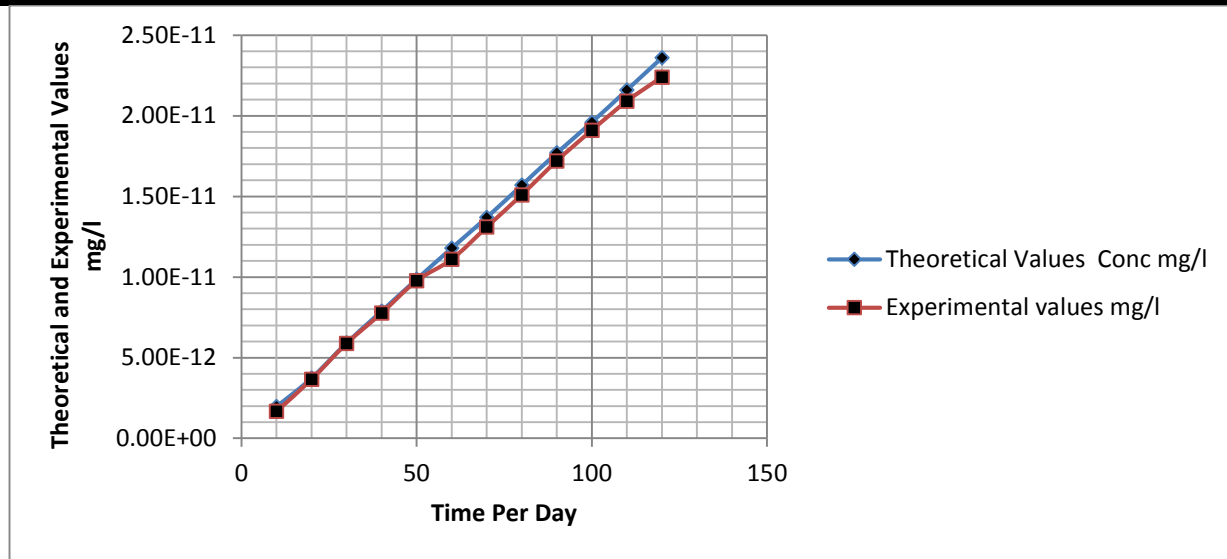


Fig.4: Comparison of Theoretical and Measured Values of virus Concentration Different Depth

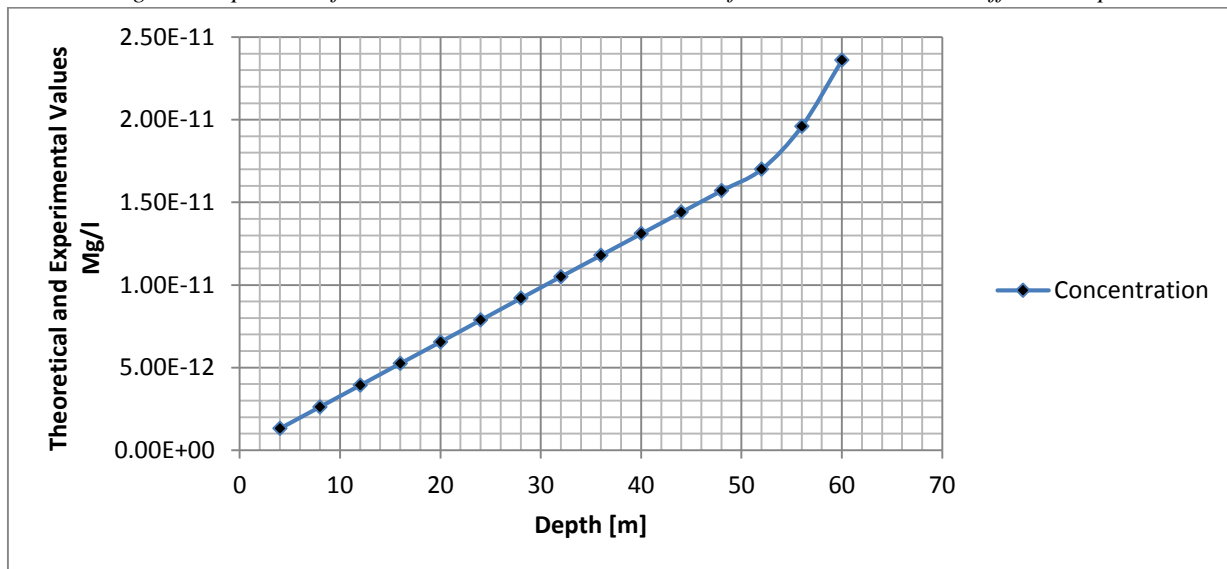


Fig.5: Theoretical values of virus concentration at Different Depths

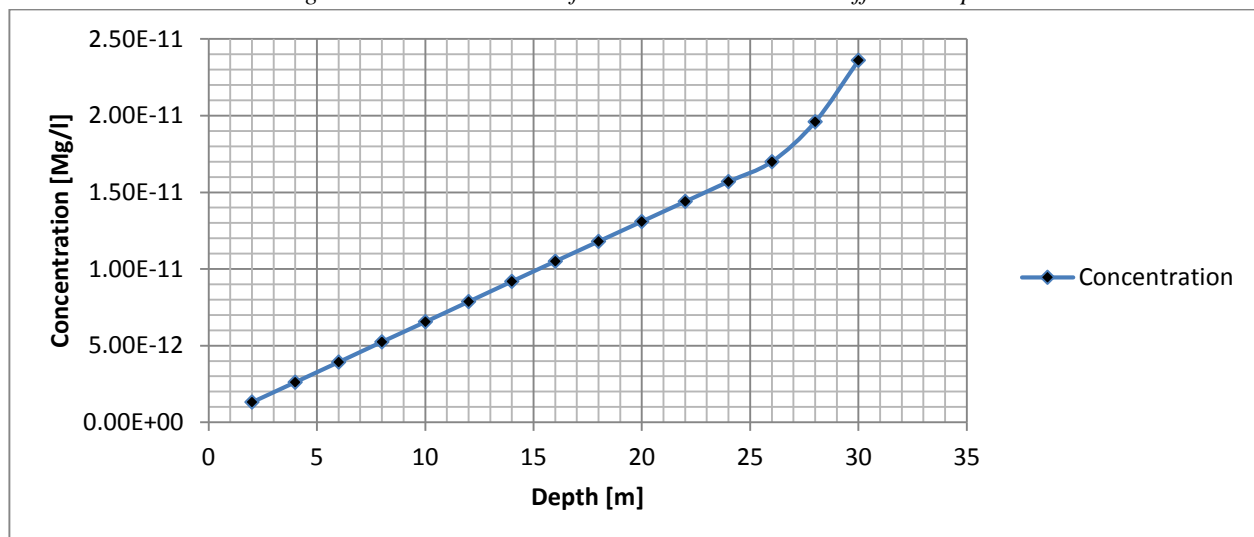


Fig.6: Theoretical values of virus concentration at Different Depths

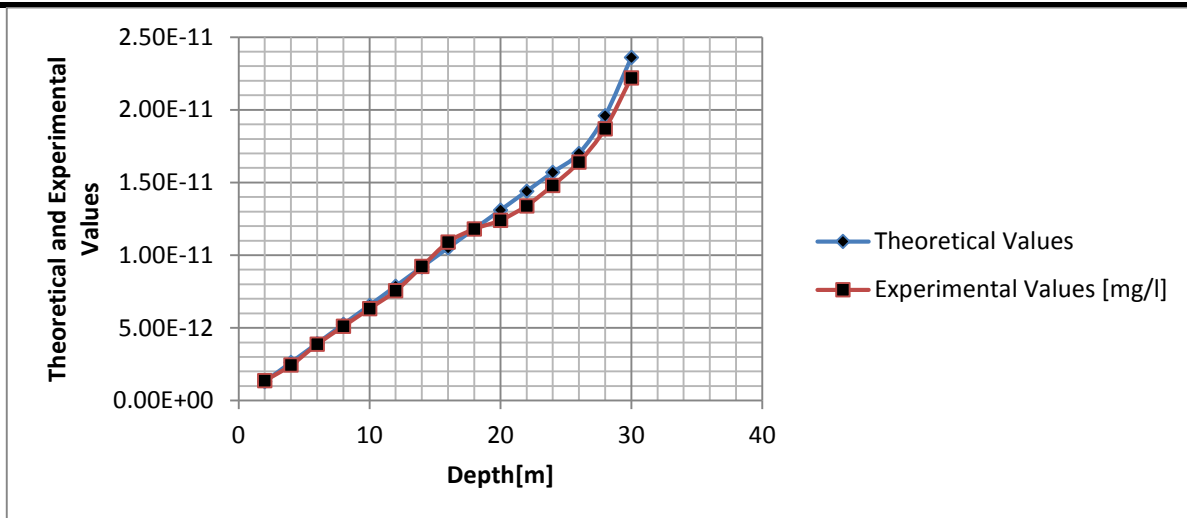


Fig.7: Comparison of Theoretical and Measured Values of virus Concentration Different Depth

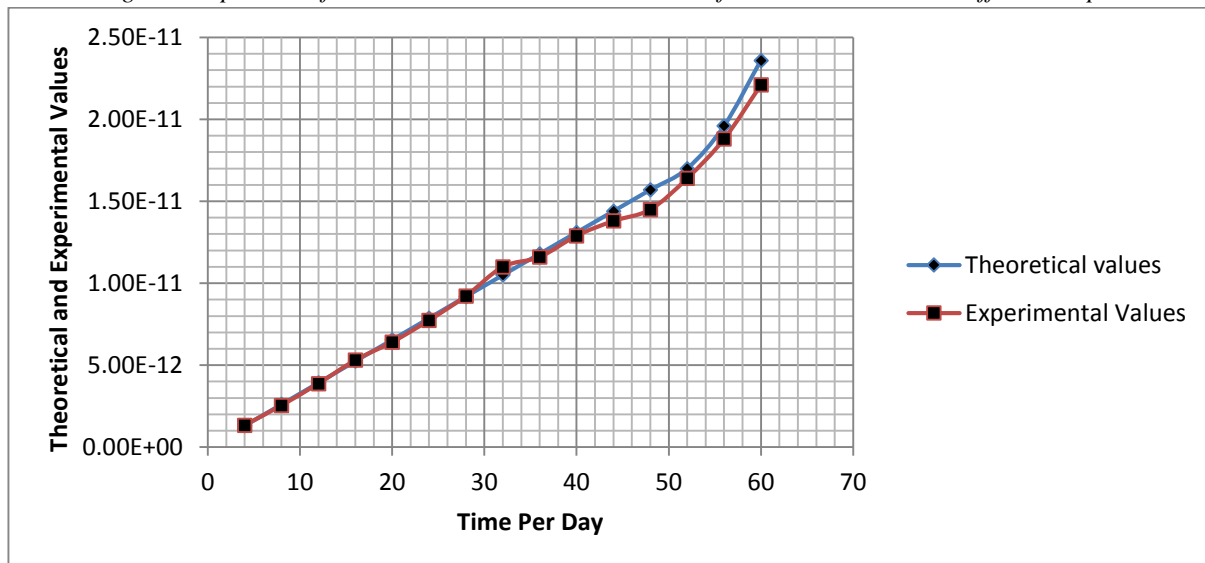


Fig.8: Comparison of Theoretical and Measured Values of virus Concentration Different Depth

Figure one to four express the behaviour of virus concentration to be linear direction under exponential phase in the transport system, the deposition of virus in those locations express homogeneous stratification of the formation. The rate of migration from the theoretical values shows that the partial deposition may have been hinder by low permeability and porosity in lateritic soil formation, but due to constant increase of saturation from high rain intensities, the concentrations find it way to the silty formation and migrate partially to unconfined bed. While four five to eight express similar condition as linear direction, predominantly influences the transport system but experiences slight fluctuation from twenty four to thirty metre at the duration of fifty to sixty day respectively, partial deposition of virus in linear direction on migration were able to establish uniformity deposition on pore

distribution of the grain size generating homogeneous void ratio, this condition may have pressure the velocity experiencing linear direction on the migration of virus, the express figure from the simulation generated values that have been compared with experimental data and both parameters developed a best fit validating the developed model for the study.

V. CONCLUSION

Partial deposition of virus were subjected to thorough investigation but the study were able generated better results that should assure that its deposit partially thus harmless to human through consumption of ground water in the study area, the deposition of virus in lateritic and silty formation establish fluctuation of permeation and pore distribution of grain size sediments, through the

development of low void ratio, these resulted to heterogeneous void ratio and porosity in lateritic and silty deposited formation. This were observed to have slightly accumulate virus concentration base on its low void ratio and porosity result to partial deposition of virus, but due to constant high rain intensities in the area virus migrated slightly to silty formation were slight higher void ratio and permeability were deposited, the velocity at those formation pressure the concentration penetrating to unconfined bed, if the deposited formation establish heterogeneity, it will definitely result to increase in concentration through an accumulation of the virus in those formation that may experience low void ratio and permeability. Just like lateritic soil deposition, Consequently, the deposition of virus lateritic soil transit to silty formation will definitely in long term accumulation thus increase its concentration, which will become severely harmful to human consuming it in borehole drill in such phreatic bed.

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